IALA

IALA GUIDELINE

G1111-7
PRODUCING REQUIREMENTS FOR RADIO DIRECTION FINDERS

Edition 1.0

December 2022

urn:mrn:iala:pub:g1111-7:ed1.0

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DOCUMENT REVISION

Revisions to this document are to be noted in the table prior to the issue of a revised document.

Date	Details	Approval
December 2022	First issue. Major revision of Guideline G1111 sections, divided into sub-guidelines G1111-1 to G1111-9.	Council 76

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1. INTRODUCTION

This Guideline presents a common source of information to assist VTS providers in the understanding of radio direction finders (RDF), supporting the design of a radio direction finding service and its contribution to the VTS traffic image (situational awareness) as well as guidance of how the VTS provider should specify the associated functional and performance requirements.

1.1. THE IALA G1111 GUIDELINE SERIES

This sub-Guideline is one of the G1111 series of guideline documents. The purpose of the G1111 series is to assist the VTS provider in preparing the definition, specification, establishment, operation, and upgrades of a VTS system. The documents address the relationship between the operational requirements and VTS system performance (technical) requirements and how these reflect into system design and sub system requirements.

The G1111 series of guideline documents present system design, sensors, communications, processing, and acceptance, without inferring priority. The guideline documents are numbered and titled as follows:

- G1111 Establishing Functional & Performance Requirements for VTS Systems and Equipment
- G1111-1 Producing Requirements for the Core VTS System
- G1111-2 Producing Requirements for Voice Communications
- G1111-3 Producing Requirements for RADAR
- G1111-4 Producing Requirements for AIS
- G1111-5 Producing Requirements for Environment Monitoring Systems
- G1111-6 Producing Requirements for Electro Optical Systems
- G1111-7 Producing Requirements for Radio Direction Finders
- G1111-8 Producing Requirements for Long Range Sensors
- G1111-9 Framework for Acceptance of VTS Systems

2. OPERATIONAL OVERVIEW

This Guideline considers application of RDF to VTS areas of responsibility. These areas may vary in the types of risks, vessels and their interactions as well as the required sensor ranges.

Radio direction finders (RDF) are a sensor system that supports VTS and SAR operation by indicating the direction/bearing to a transmitting station. Since an RDF only indicates the bearing of the transmitting station relative to the RDF sensor location, two or more appropriately located RDFs are needed to estimate the position of the transmitting station. In essence RDF provides a visual indication of position or bearing line for the VTS operator (VTSO)O and significantly improves spatial awareness.

The necessary functional and performance requirements may differ throughout the geographical area of VTS responsibility and as such they should align to the risks being mitigated and to facilitate VTS operations. For example, RDF can be particularly effective in high volume transit areas or a Traffic Separation System (TSS) where vessels are continuously reporting in to VTS providers even if the VTSO only sees a bearing line.

VTS providers should consider the need for an RDF system based on the type of traffic in the VTS area, such as the presence of non-SOLAS class vessels and recreational vessels that do not carry an AIS transponder (assuming the VTS is able to receive AIS data). VTS providers should also consider other factors such as:

- the features of the VTS area, such as extent of area of responsibility and availability and distribution of Marine Aids to Navigation; and
- radio environment such as noise floor, presence of other transmitters.

When a RDF system is assessed as being necessary, the VTS provider should, at least, consider the following:

- The required RDF coverage area, based on:
  - possible RDF location(s);
  - waterway structure and navigational hazards;
  - the types of ships to be detected; and
  - expected meteorological conditions.
- The required bearing accuracy
- Presence of 3rd party sources of electrical and RF noise
- The required frequency range of the RDF equipment (this may e.g. include frequencies used for SAR)
- The number of simultaneously monitored VHF channels
- RF path across land and sea which can degrade performance
- Other influencing factors, such as obstructions in the line of sight as well as objects behind the RDF aerial and the presence of potential reflective surfaces, which may reduce the performance of an RDF system

3. PRODUCING FUNCTIONAL AND PERFORMANCE REQUIREMENTS

The requirements should be based on the high level approach described in IALA Guideline *G1150 Establishing, Planning and Implementing VTS*. This concluded that the feasibility study on risk should specify the risks within the interested area and the means to address or mitigate such risks.

3.1. AREA OF COVERAGE

The RDF coverage area needs to be consistent with the results of risk assessment and possible VTS responsibilities for SAR. Factors affecting the detection performance of RDF systems, including potential interference and propagation characteristics, should be taken into account as well as special local conditions, such as heavy rainfall.

In order to allow confirmation of the position of a transmitting station in the main area of operation with two or more RDF stations, the bearing angles on target should cross close to 90º (the position accuracy with two or more RDF stations degrades very rapidly when the bearing angles do not cross at 90º; in the extreme cases of 0º and 180º crossing angles no position estimation is possible). This may pose significant restrictions on the potential locations of the RDF stations. The recommended method for determination of RDF coverage and range performance is a combination of site inspections and RDF system performance calculations. See Figure 1 which provides an example of such a calculation.

The evaluation should include:

- calculation of VHF Radio Range based on RDF antenna height and minimal VHF antenna height on the target of interest;
- calculation of all applicable losses (target's VHF transceiver power, required RDF sensitivity, losses in VHF cable etc.);
- evaluation of the effects from propagation conditions and obstructions; and
- influence of meteorological conditions.

The calculations may be supplemented by comparison and/or validation test.

Distinguish between less critical areas covered by a single DF only for directional information and areas with accurate geolocation covered by at least two direction finders. Site survey has been mentioned but not only obstacles shall be considered, nearby radio transmitters / radar antennas are even more critical.

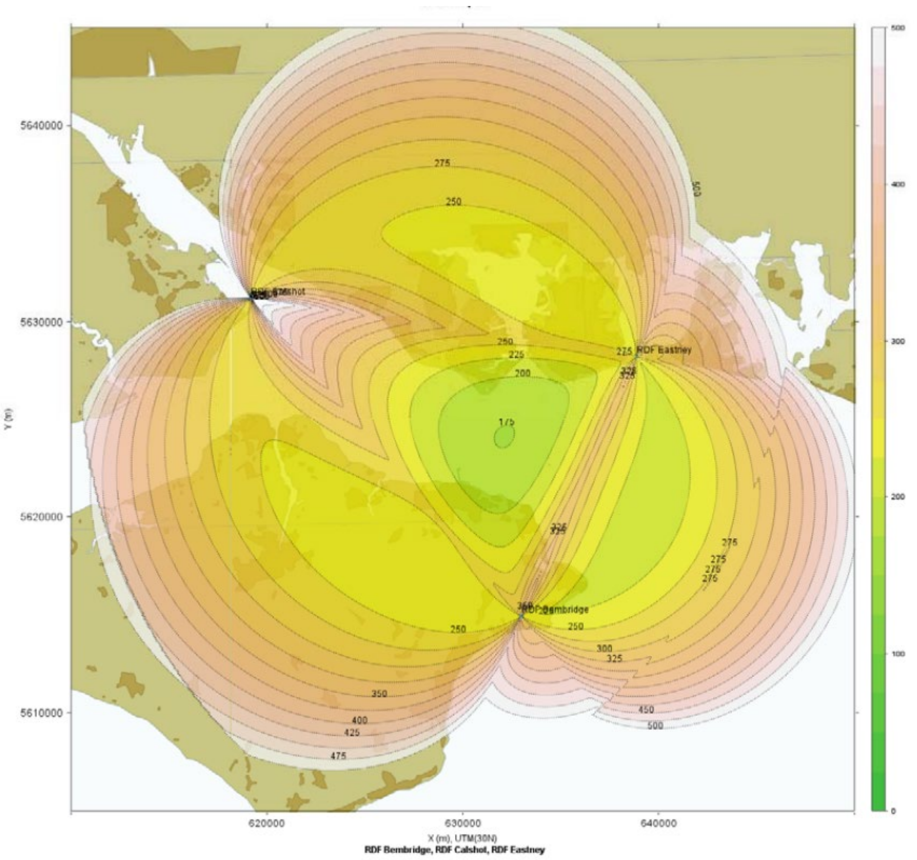

Figure 1 Radio direction finder performance

3.2. BEARING ACCURACY

One of the most important performance parameters of the radio direction finder system is the bearing accuracy. Besides the technical characteristics of the RDF equipment, many other factors may significantly reduce the bearing accuracy in real conditions. Therefore, the following aspects should be taken into account when assessing bearing accuracy:

- The specified RDF equipment bearing accuracy. The recommended bearing accuracy depends upon the functional requirements for each particular VTS area and the reason for including a RDF as a sensor. Suppliers can provide specifications for each model but typically vary between ≤ 5˚ and ≤ 2˚. However accuracy continues to evolve with some equipment able to provide <= 1° RMS accuracy. Selectivity becomes important when monitoring channels that have similar or adjacent frequencies.
- Area of responsibility operation
- The environment of the RDF antenna
- Multipath signal propagation, caused by reflections from surrounding objects, can significantly deteriorate the bearing accuracy. DF antennas with high immunity against reflections are helpful e.g. wide-aperture antenna with at least 2.5 m diameter.
- The received signal strength. Low received signal levels may significantly reduce the bearing accuracy. Major factors affecting received signal strength are:
  - distance to the target;
  - RDF receiver(s) sensitivity, antenna gain and feeder losses;
  - weather conditions; and
  - output power and duration of transmitted signal.
- The delay between signal detection and output for presentation should aim to be less than 1.5 seconds and no more than 2 seconds.

  The main cause of this delay is the internal processing of the received signal within the RDF system to achieve declared accuracy. VHF DF is particularly helpful in determining the source of jamming and interference. Active adaptive interference cancellation of maritime Tx antennas can be installed on the same mast as the DF antenna

In order to achieve the best possible performance, proper on-site calibration is essential and will mitigate against the adverse effects of some of the factors listed above.

3.3. FREQUENCY RANGE

Since the main purpose of RDF is detection of VHF communication devices, the frequency range of RDF should, at least, correspond to the frequencies specified through Appendix 18 of the International Radio Regulations, for the International Maritime VHF band (156.0125 - 162.0375MHz). Additionally, support for 121.5 Mhz for homing for civilian beacons (and 243 Mhz for military) may be required if the VTS provider has a responsibility for SAR operations.

3.4. NUMBER OF SIMULTANEOUSLY MONITORED VHF CHANNELS

RDF may support simultaneous or almost simultaneous reception on multiple VHF frequencies via the use of solid state receivers which can scan multiple channels simultaneously. For example, SAR channels and VHF channel 16 may be required to be monitored simultaneously, while all other VHF working channels are monitored selectively.

RDF receivers should, as a minimum, include:

- remotely controlled selection of VHF channels for each receiver;
- automatic channel scan function from a pre-defined list of working channels for one or more receivers;
- simultaneous output of detected bearings for all receivers; and
- remote access and remote testing and diagnostics.

3.5. ALGORITHMS

In terms of the mathematical algorithm used in RDF systems, manufacturers typically use the principles of amplitude comparison or phase comparison and each have their own characteristics for all applications.

- *Doppler*

  Uses the doppler shift induced by a received signal and measuring the phase relationship across a number of elements in a DF receiver aerial.

- *Correlative interferometry*

  Uses phase difference from signals received across a number of elements within the DF receiver aerial

- *Watson-watt (or Adcock)*

  This method measures the phase difference between across pairs of aerials

3.6. SEARCH AND RESCUE (SAR) FUNCTIONALITY

Where VTS providers have SAR responsibilities, additional functionality of RDF equipment may be required, such as the detection of EPIRB and ELT devices transmitting on SAR homing frequencies such as 121.5 Mhz. Note that homing signals from ELT or EPIRB devices are normally weak (max. 5 W with 500 ms duration, or only 100 mW continuously with a small antenna at sea level) and consequently are difficult to be detected at long distance.

3.7. SPECIFIC DESIGN, CONFIGURATION, INSTALLATION AND MAINTENANCE CONSIDERATIONS

The RDF system should be specified based upon risk and operational requirement however there are practical elements to consider such as maintenance access, lightning protection and wind load on the radio tower or mast antennas. Environmental factors such as the build-up of ice in some climates should also be a consideration.

3.7.1. ANTENNA INSTALLATION

RDF antenna installation requires careful consideration, especially with regards to the site. The following aspects should be considered:

- The RDF antenna should be placed on a very stable support to avoid any rotation or torque as this directly affects RDF bearing accuracy.
- The antenna height should be sufficient for detection of VHF transmissions from the targets of interest across the coverage area.
- The presence of objects and geographic features that might cause reflections or the blocking of signals; Rotating or moving objects (like radar antennas and Pan Tilt Zoom (PTZ) CCTV) should be a safe distance from the RDF antenna (refer to the manufacturer’s instructions) .
- Provision of utilities such as electrical power and remote connectivity.

- Typically, a RDF antenna is placed on the very top of a mast, so special attention should be paid to lightning protection of the structure without causing reflections and/or obstruction of incoming VHF signals.

3.7.2. SYSTEM INTEGRATION

VTS providers should be aware that most RDF systems are IP-based and use common standards and format to allow integration and presentation on to the traffic image.

3.7.3. MONITORING AND DIAGNOSTIC FUNCTIONALITY

Built-in test features should include monitoring of functions and performance and should be accessible remotely.

3.7.4. CALIBRATION

This should be undertaken as part of the manufacturing process during factory acceptance tests and final adjustment during site/system acceptance tests. During service operations VTSOs should verify performance and accuracy through the use of targets of opportunity and compare bearing readings with other sensors such as radar and AIS. When integrating and comparing an RDF-bearing with a radar position on a screen a possible error may be introduced by the projection being used in the radar application. For example, if Mercator is being used the angle of the RDF-bearing will be correct, however if UTM is being used a systematically error, if not corrected for, may be introduced between 0 – 2.4 degrees depending on the position of the RDF and the ship position.

Ultimately calibration and performance checks should be performed according to the manufacturer's instructions and should be reviewed if there are significant changes to the equipment and/or environment.

4. DEFINITIONS

The definitions of terms used in this Guideline can be found in the International Dictionary of Marine Aids to Navigation (IALA Dictionary) and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

5. ABBREVIATIONS

Please refer to IALA Guideline *G1111 Establishing Functional and Performance Requirements for VTS Systems and Equipment* for an extensive list of abbreviations covering the entire G1111 series.

6. REFERENCES

[1] IALA. G1111 Establishing Functional and Performance Requirements for VTS Systems.

[2] IMO. (1974) Convention on Safety of Life At Sea (SOLAS 1974) (as amended).

[3] IALA. Guideline G1150 Establishing, Planning and Implementing a VTS.